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Transportation Research Procedia 18 (2016) 100 – 107

Transportation Research Procedia

www.elsevier.com/locate/procedia

XII Conference on Transport Engineering, CIT 2016, 7-9 June 2016, Valencia, Spain

Economic crisis and its influences on the interaction between land use and transport in Madrid Region

Yang Wang [a]*, Andres Monzon [b]

[a] PhD, Transport Research Centre (TRANSyT), Universidad Politecnica de Madrid, Calle Profesor Aranguren s/n, 28040 Madrid, Spain
[b] Professor, Transport Research Centre (TRANSyT), Universidad Politecnica de Madrid, Calle Profesor Aranguren s/n, 28040 Madrid, Spain

Abstract

The economic and financial crisis has been impacting European countries since 2008 at different degrees.This paper aims to find out if the statistical analysis of land use and mobility can help to answer the question of what happens during economic crisis on both land use and transport system, and unveiling key spatial relationships between them.

The methodology for the analysis was developed accordingly with the data and resources available. First, an exploratory data analysis (EDA) is performed in order to identify the land use and mobility pattern during the last decade. It focuses on six aspects, which are distribution of population and dwellings, employment and jobs, GDP, motorization and modal split. The second aspect consists on crossing the spatial patterns of the different aspects in order to find some explanatory relationships that indicate the presence of the key characteristics.

Through the exploration analysis, we find that there is a close relationship between the land-use system and travel behaviour in Madrid Region. With an increasing of new dwellings constructed in the outer periphery of Madrid Region, it leads longer trips distance and more travel cost particularly by car mode. Moreover, during the economic crisis, we also find the motorization level of Madrid keeps the same, as a result of the decreasing GDP and relatively decreasing household income.

Peer-review under responsibility of the organizing committee of CIT 2016

Keywords: Economic crisis, land use and transport interaction, Madrid

* Corresponding author. Tel.:+34 91 336 5234; fax: +34 91 336 5362.
E-mail address: yang.wang@upm.es (Y. Wang), andres.monzon@upm.es (A. Monzon)

Peer-review under responsibility of the organizing committee of CIT 2016
doi:10.1016/j.trpro.2016.12.014

1. Introduction

During the last decade, Spain fell into a great recession from a fast economic growing during the 90s to 2006. Between October 2007 and October 2008, Spain had its unemployment rate climb 36%, exceeding by far the unemployment surge of past economic crises like 1993 (Suarez, 2010). Spanish government therefore launched a series measures as called austerity packages in order to restore its credibility and reduce the budget deficit (Elteto, 2011).

The consequences of the crisis on land use and transport include reduced housing price, less travel demand, stagnant car ownership and increased public transport fare, etc. Numerous researches illustrate the effects of the global economic crisis changing transport behaviour (Ulfarsson et al., 2015; Nielsen, 2015). Macroeconomic variables such as per capita income levels or unemployment rates could have an important influence on transport demand as well as peoples' activities (Cordera et al, 2015). However, it is not clear how the economic crisis influences the interaction between land uses and transport, particularly the influences at different spatial scale. Therefore, this paper aims to find out if a statistical analysis of land uses and mobility can help to answer the question of what happens during economic crisis on both two systems, and unveiling key spatial relationships between them.

On the other hand, many academic proved the land-use system and transport system are closely linked (Harris 1965; Lee 1973; Batty 1994; Harris 1994; Hayashi & Kenji, 1989; Wegener, 2004). The distribution of land uses, such as residential, industrial or commercial, determines the locations of people activities, like living, working, shopping, education or leisure; on the contrary the distribution of people activities requires trips in the transport system to overcome the distance between the locations of activities (Wegener, 1999). However, there are apparently new changes on this typical relationship during the economic crisis (Geels, 2013).

The methodology for the analysis is developed accordingly with the data and resources available. First, an exploratory data analysis (EDA) is performed in order to identify the land use and mobility pattern during the recessionary phases. Land use impacts are defined in terms of the characteristics of the residential location of the individuals: population density, distribution of workplaces and employees, and other economic indicators. The second aspect consists of crossing the spatial patterns of the different aspects in order to find out how the economic recession undermines people's activities and mobility patterns.

The study is based on the case of Madrid Region, one of the European cities more affected by the crisis. The economic recession of Spain starts from the end of 2008 with the housing bubble, the banking crisis and the rise in unemployment in Spain. The data used in this analysis are from two years, 2004 when Spain still experiencing a fast economic growing, and 2014 which Spain was falling into the chasm of economic recession. It is meaningful to analyse the changes between the two years in order to find out the influence on mobility and land use results in the economic crisis. The data are collected from the national statistical institute, the regional government database and two urban mobility surveys of Madrid (i.e., EDM´04 and ESM´14).

The remainder of the paper is organized as follows. The next section first provides an updated mechanism of land use and transport interaction during the economic crisis. Then, it begins with the analysis of the influences of the economic crisis, on the land use changes and on the mobility changes. The results of the cross analysis are also presented and discussed in this part. Last, concluding remarks are offered.

2. An updated mechanism

A typical mechanism of the interaction between land use and transport is that the economic growth raises trip demand as the result of increased production and income growth, and higher income stimulates car ownership and leads more car-dependency (Hayashi, 2003). Yet, a great economic recession causes a different pattern of the interaction between land use and transport. The effects have resulted in a reduction of the economic activity,

weakening public services and the welfare system. The updated mechanism is illustrated in Figure 1.

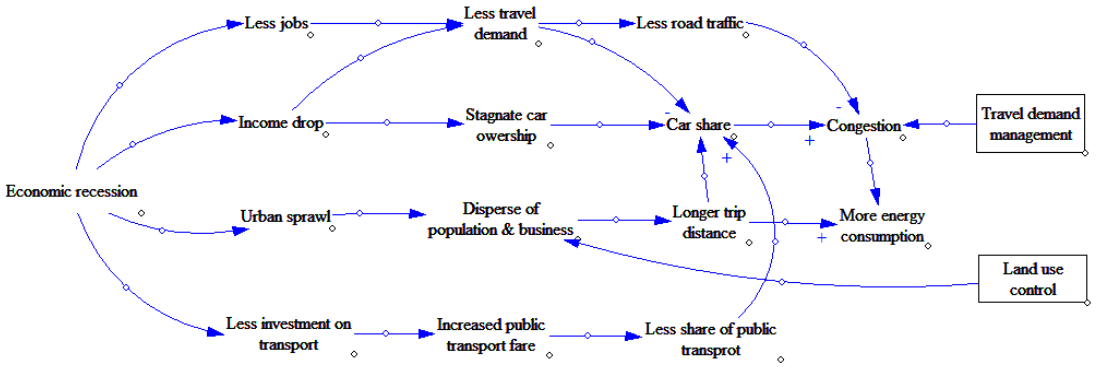

Fig. 1. Mechanism of the interaction between land use and transport in crisis

The economic recession firstly leads a fast drop of household income and high unemployment, which causes people moving to a cheaper place to live. Since housing in the suburb usually costs less than in the centre, it attracts urban sprawl. The dispersed relocation of population and housing encourages longer trip distance as well as more car dependency.

On the other hand, travel demand also decreases resulting in the household income reduction and high unemployment. At the same time, the local government reduces the investment to subside the public transport, i.e., increased PT (public transport) fare and less frequency. All of those cause people making longer trip distance and using less public transport, which worse the urban congestion and high energy consumption.

From the mechanism chart, it can be seen the direct effect of economic recession, but it is not clear the influences of the economic crisis at different spatial scale. The following part therefore elaborates the analysis on focusing on the impacts of the economic crisis on land use and transport.

3. The impacts of the economic crisis

3.1 Study area

To assess the impact of the economic crisis on land use and daily mobility, we focus on different spatial level of the study area, the Madrid Region. The Madrid Region is located in the centre of Spain with a population of more than 6 million people and covers an area of 8,030 km². Figure 2 presents the map of the Madrid Region that is distinguished in three study areas, i.e., the main city, the metropolitan ring and the regional ring.

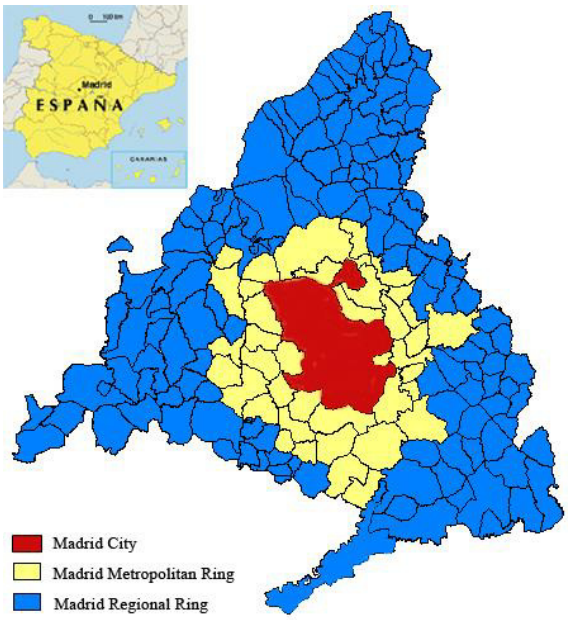

Fig. 2. Madrid Region Map

There are two aims to distinguish the Madrid Region in these three areas. Firstly, it can determine the phenomenon of urban sprawl by studying on the indices of land use of the three areas. Secondly, they represent different scales of land use with different economic level, so it could help to answer the question of how the economic recession changes people daily activity.

The main city has closely 50% of the population, the highest population density (14 million people per km^2) and the most expensive land price (€2,911 per m^2), but also owns the best transport connection both for private and public. The metropolitan ring is the Madrid Metropolitan Area but minus the main city. This area is used to represent the average level of Madrid Region, an average impact of economic crisis to land use and mobility. The regional ring consists of the largest number of municipalities of Madrid, but has the lowest population density (4 million people per km^2). People in this area generally are less influenced by the economic recession because their specific economic characteristics.

3.2 The economic crisis on urban sprawl

Table 1 shows the economic indices and land use data including number of residents, population density, number of employees, number of workplaces, number of dwellings, and average housing price of the Madrid Region as well as the three studied areas.

Table 1. Economic indices of Madrid in 2004 and 2014 (INE, IEM)

Year	Whole Region	In Region Ring	In Metropolitan Ring	In Main City
		Nº of Residents		
2004	5,867,299	350,110	2,354,885	3,162,304
2014	6,518,768	467,579	2,797,454	3,253,735
		Population Density (1000 person/km2)		
2004	4,020	132	1,606	14,410
2014	4,134	195	1,854	14,390
		Nº of Employees		
2004	2,706,922	156,068	1,117,657	1,433,197
2014	2,163,442	144,551	1,033,725	985,166
		Nº of Workplaces		

2004	2,215,806	63,587	710,689	1,441,530
2014	2,523,666	87,161	913,490	1,523,015
		Nº of Dwellings		
2004	2,451,272	198,417	816,431	1,436,424
2014	2,894,680	278,370	1,085,360	1,530,950
		Average Housing price (€/m^2)		
2004	2,576	2,076	2,361	3,401
2014	2,335	1,838	2,051	2,911

During the economic crisis, Spain's unemployment rate hit 17.4% at the end of March 2009, with the jobless total now having doubled over 2008, when two million people lost their jobs (Suarez, 2010). Similarly, 20% more unemployment arise in Madrid Region, particularly in the main city (31% less employees), although the number of workplaces is increasing as a result of numerous small companies emerged. After the housing bubble burst in Spain, the housing price drops 9% in Madrid, especially in the main city (14% less) and the metropolitan ring (13% less). These economic indices show a notable economic recession in Madrid region in the last decade.

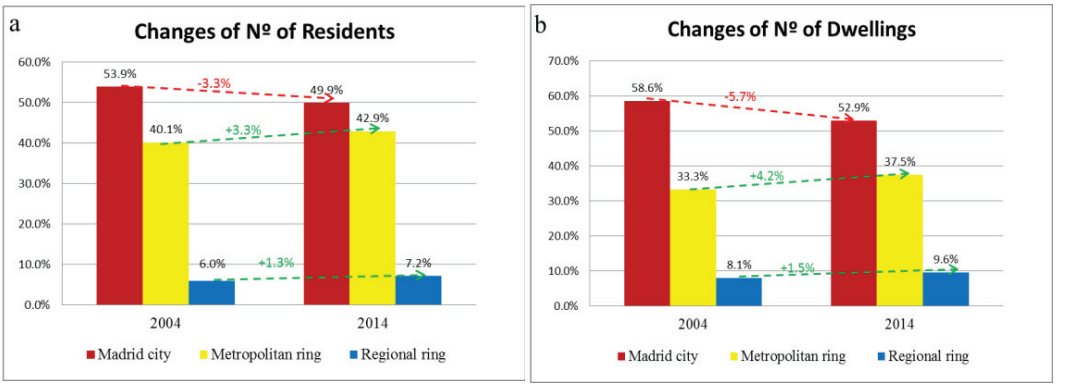

Fig. 3 (a) The changes of the proportion of residents of Madrid in 2004 and 2014; (b) The changes of the proportion of dwellings of Madrid in 2004 and 2014

Figure 3 shows the changes of the spatial distribution of residents and dwellings between 2004 and 2014. In total, there are 651 thousand more residents and 443 thousand of new dwellings grown during the decade from 2004 - 2014. It can be seen a number of residents move out from the main city to the suburb where 79% of new houses were constructed during the last decade. It leads the population density slightly reduced in the main city and extremely increased in the regional ring (47% more) and in the metropolitan ring (15%) of Madrid region (table 1).

Owing to the lower land price in the periphery of the region, there are 18% new dwellings were built in this area and meanwhile attract 18% of new residents live here. The metropolitan ring and the regional ring has 4.2% and 1.5% respectively more proportion of new dwellings and drew around 67.9% new residents. On the contrary, the main city of Madrid lost 3.3% proportion of residents and 5.7% proportion of dwellings. Comparing with the average increasing rate of population from 2004 to 2014, a large number of people move to the periphery of the region and the urban sprawl indeed occurred.

3.3 The economic crisis on mobility changes

Table 2 lists the indices of mobility changes in Madrid between 2004 and 2014. The total travel demand significantly reduced, 11% less daily trips and 29% less work related daily trips in 2014 comparing with 2004. Meanwhile, Madrid residents have reduced their daily trips from 2.5 to 2 times per day. That is consistent with the fact of the household income decline and unemployment increase. As seen as the average car occupancy, it is changed

from 1.28 to 1.56, which implies there are less single drivers now. All these facts show that people make less unnecessary trips or use their car in a more efficient way during the economic crisis.

Table 2. Mobility changes of Madrid in 2004 and 2014 (EDM´04 and ESM´14)

Year	Nº of trips/day (10^3)	Nº of trips to work or related (10^3)	Nº trips per person/day	Average car occupancy	Approximated average trip Distance (Kilometre)
2004	14,511	4,412	2.5	1.28	11.04
2014	12,925	3,132	2	1.56	12.12

Taking into account the average trip distance, it is approximately calculated as Equation (1).

$$d = \frac{\sum_{i=1,\, j=1}^{90} D_{ij} * T_{ij}}{\sum_{i=1,\, j=1}^{90} T_{ij}} \tag{1}$$

D_{ij} is the distance between the geometric centroid of every two municipalities (i.e., *i* and *j*) of Madrid; T_{ij} is the total number of trips between municipality *i* and *j*. Through the calculation, it is found that although the average trip length has only 10% increasing in 2014, there is 16% total trip distance increasing in the main city, particularly among the metropolitan ring (65% more) and regional ring (20% more). The effect of urban sprawl on trip distance is high.

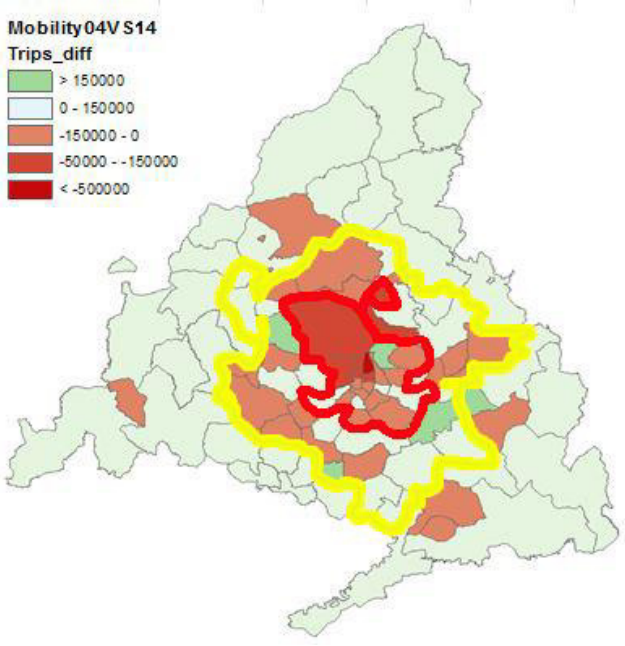

Fig. 4. Changes of the total number of trips 2014-2004 (EDM´04 and ESM´14)

Study on the spatial changes of mobility, figure 4 illustrates the changes of the total number of trips between 2004 and 2014. The green color meaning trip increasing mostly appears in the regional ring. And the red one which is trip reduction centralizes in the main city and part of the metropolitan ring. Though the total number of trips is reducing in Madrid Region, a great number of trips by car appear in the Regional ring (+17%) and the metropolitan ring, it leads to longer trip distance which implies more energy consumption and more negative external effects.

3.4 Economic recession and modal share

This part presents the economic indices; following on that figure 5 illustrates the relationship of the gross domestic product (GDP) and car ownership growth by year on the basis of 2003. Owing to the economic recession, the GDP of Madrid started dropping from 2009. Consequently the car ownership has reduced in 2007 and kept the same level during the whole period of the economic crisis.

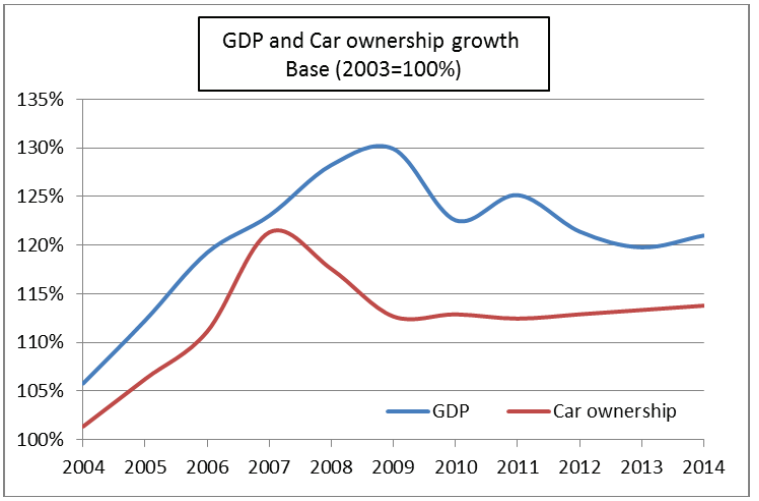

Fig. 5. GDP and employment changing from 2001 to 2014 in Madrid (IEM)

The reduced GDP leads people containing the cost of living, including the transport spending, which is corresponding to the reduced travel demand that is shown in table 2. However, the decreased income and car ownership of Madrid does not lead less car sharing. Table 3 presents the percentages of the modal share of the three study areas of Madrid.

Table 3 – Percentages of modal share of Madrid in 2014 and 2004 (EDM´04 and ESM´14)

	Whole Region		Regional ring		Metropolitan Ring		Main city	
Year	2004	2014	2004	2014	2004	2014	2004	2014
Car (%)	35.4	41.0	53.8	68.3	44.5	53.0	28.1	30.0
PT (%)	32.5	27.8	14.4	10.9	20.8	16.0	41.4	37.8
Walking (%)	31.2	29.9	31.7	20.8	34.4	30.0	29.1	30.7
Others (%)	0.9	1.3	1.0	0.02	0.3	1.0	1.3	1.6

As it is shown in Table 3, there is a great decreasing (4.7% less) on the public transport (PT) share in Madrid. The main reason caused the drop of PT share is the worse of PT service. As the consequence of the economic crisis, Spanish government launched a series of austerity packages including reducing the subsidy to public transport operations. From 2009 to 2014, the single PT ticket in Madrid has increased 30% and monthly ticket increased around 60%, the biggest rise in 10 years. At the same time, the frequency of bus and metro is reduced. Owing to these reasons, more and more travelers have shifted to car mode (5.6% more) for the last decade.

It is interesting to observe the data in different territorial scale. In the regional ring, as the population density (table 1) increasing and longer trip distance, there are 14.5% more trips made by car and 3.5% less trips by public transport and almost 11% less by walking. Similar changes appeared in the metropolitan ring, more car sharing and less PT and

walking share. In the main city, the changes of modal share are a bit different. There are more travelers (3.6% more) choose to walk or using other modes (i.e., taxi, bicycle, car-pooling, etc.) instead of using car of public transport. Thus, the increasing of car share is less than the average, and more share of walking mode. Similar found appears in the modal share for work related trips, a big increase in car share, and deceasing for public transport share mainly owing to the high raised tariffs.

4. Conclusions and discussions

In summary, this study indicates that economic recession does influence on land use characteristics and mobility system as well as the interaction between them. Travel demand declines and trip distance increases as population and business disperse. GDP as an indicator for economic activity is important in determining mode share and car ownership.

Most significantly, as the level of PT service decreases, the use of public transport decreases and car use increase in the whole region. It leads to more congestion and energy consumption. In addition, public service level decline, as measured by bus frequency and fare appears to be a more important determinant of mode choice than car ownership. Finally, long trip distance and more car share are key factors of road traffic. It encourages more energy consumption and discourages non-motorized mode like walking or cycling.

These results show a close link between land use and transport and have clear implications for transport policy and sustainability. The economic crisis is a double-edged sword, it is a damage, but it is also an opportunity. For policy makers, it is important to attempt to launch certain policy measures like travel demand management or land use control to solve the problems. Travel demand management measures like reducing car use, better public transport service can encourage more sustainable travel patterns. Land use control such as compact land use development can restrain widely outspread residential development.

For future study, we will investigate on the land use impacts of the local access to public services and other activities like shopping and leisure; the mobility influence like urban congestion. Moreover, study on the energy consumption and comparing the influence of Madrid with another city of Spain, like Barcelona is also expected.

References

Batty, M., 1994. A Chronicle of Scientific Planning: The Anglo-American Modeling Experience. Journal of the American Planning Association 60, pp. 7-16.

Consorcio de Transportes de Madrid EDM'04.2006 Encuesta domiciliaria de movilidad en día laborable 2004.

Éltető, A., 2011. The economic crisis and its management in Spain. Eastern Journal of European Studies 2(1), 41-55.

Geels, F.W., 2013. The impact of the financial–economic crisis on sustainability transitions: Financial investment, governance and public discourse. Environmental Innovation and Societal Transitions 6, 67-95.

Harris, B., 1965. New Tools for Planning. Journal of the American Institute of Planners 31, 90-95.

HarriS, B., 1994. Science in Planning: Past, Present, Future. Journal of the American Planning Association 60, 31-42.

Hayashi, Y., Kenji D., 1992. Benefit Incidence of Outer Urban Ring Roads – Theory and Case Study of the Nagoya Ring Road. Land Use, Development and Globalisation. Selected Proceedings of the Sixth World Conference on Transport Research, Lyon.

Hayashi, Y., ROY, J., 2013. Transport, land-use and the environment. Springer Science & Business Media, 3-21

Hensher, D.A. ed., 2004. Handbook of transport geography and spatial systems (Vol. 5). Elsevier.Vancouver

Lee, D.B., 1973. Requiem for Large-Scale Models. Journal of the American Institute of Planners 39, 163-78.

Nielsen, T. A. S., 2015. Changes in transport behaviour during the financial crisis. An analysis of urban form, location and transport behaviour in the greater Copenhagen area 2006–2011. Research in Transportation Economics, 51, 10-19.

Suarez, J., 2010. The Spanish crisis: background and policy challenges. CEMFI Working Paper 1005

Ulfarsson, G. F., Steinbrenner, A., Valsson, T., Kim, S., 2015. Urban household travel behaviour in a time of economic crisis: Changes in trip making and transit importance. Journal of Transport Geography, 49, 68-75.

Wegener, M., 2004. Overview of land-use transport models. Handbook of transport geography and spatial systems, 5, 127-146.